BENTON HARBOR POWER PLANT LIMNOLOGICAL STUDIES

PART XI. WINTER OPERATIONS 1971-1972

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INTRODUCTION

In Part VII (March 1971) of our report series relative to the Donald C. Cook Nuclear Station, we established the following report format:

A. COOK PLANT PREOPERATIONAL STUDIES

- A.1 Recording of Local Water Temperatures
- A.2 Study of Floating Algae and Bacteria
- A.3 Development of a Monitor for Phytoplankton
- A.4 Study of Attached Algae
- A.5 Study of Zooplankton
- A.6 Study of Aquatic Macrophytes
- A.7 Study of Benthic Organisms
- A.8 Study of the Local Fishes
- A.9 Support of Aerial Scanning

B. SURVEYS OF EXISTING WARM WATER PLUMES

C. THE ICE BARRIER AT THE COOK PLANT SITE

D. EFFECTS OF EXISTING THERMAL DISCHARGES ON LOCAL ICE BARRIERS

E. EFFECTS OF RADIOACTIVE WASTES IN THE AQUATIC ENVIRONMENT

- E.1 Gamma Scan of Bottom Sediments
- E.2 The Most Sensitive Organism for Concentration of Radwastes
- E.3 Study of Lake Michigan's Present Radioactivity Content (FINISHED)

This report covers only items C and D of the above format; the others were brought up to date in Part X (August 1972).

This report of the operations of the winter of 1971-1972 is a follow-up to the reports of the studies of the two previous winters:

Part V Winter Operations, March, 1970

Part VIII Winter Operations, 1970-1971

The formation of the several ice ridges and the other characteristics of the ice along this shore were discussed at some length in Part VIII.

ACKNOWLEDGEMENTS

We gratefully acknowledge assistance received from Dr. Samuel Mozley, Mr. Jon Barnes, and from Ames/Warnock, commercial photographers from Benton Harbor.

Photographs not otherwise accredited were taken by W. L. Yocum.

ILLUSTRATIONS

Because of the cost of duplicating the large number of color photographs involved, the full report is being prepared in only two copies. One copy will be presented to the Michigan Water Resources Commission; and the other copy will be retained on file by the Great Lakes Research Division.

C. THE ICE BARRIER AT THE COOK PLANT SITE

The ice season of 1971-72 began on 10 December when the beaches froze. There was no ice build-up until the night of 5-6 January 1972 when the lake became heavily laden with slush, and a storm icefoot formed overnight. Slush was absent from the inshore water on 5 January, but extremely abundant on 6 January. The origin of the slush can only be surmized, but its sudden appearance could have been due to a heavy snowfall over the lake.

The icefoot of 6 January grew very rapidly during that day, but the ice formed was of a coarse, porous, granular nature, and the icefoot was almost completely melted away by 10 January.

Ice that formed subsequently, particularly during a major storm on 24 January, was the typical compact aggolomerate dominated by ice balls and spray ice. This ice remained along the shore until the April melt.

The demise of the shore ice complex was a quiet melting in place, the same ridges remaining visible from 9 February through 20 March. Final melting was nearly complete on 3 April.

Figures 1 through 5 show the frozen beach condition on 13 and 29 December and on 5 January. In Figure 5 the actual edge of the frozen sand shows as a line in center foreground at the edge of wave-wash. Figure 6 presents a closeup of the frozen edge with minor erosion of unfrozen sand on the left produced as wave-wash ran back off the frozen sand.

Figure 7 looks down from the bluff at the visitors center and shows, lakeward of the bare beach, the icefoot which formed during the night of 5-6 January; this picture was taken in the early morning.

The view in Figure 8 is south of the plant and shows the extent of the icefoot there in late morning. Growth has been so fast that blowholes have developed and become extinct as lakeward extension of the ice shut wave action away from them. The uniform granular nature of the ice is visible.

In Figure 9 a small ridge of very sandy ice lies at the foot of the beach. It appears that this represents the initial formation of ice during the night of 5-6 January. Frozen wave-wash shows on the beach beyond the blocks. In the foreground is the granular ice that was forming on 6 January.

Figure 10 is a detail of the frozen wave-wash landward of the icefoot. It appears that this might have been an initial high wave containing slush.

Figure 11 looks southward along the ice face south of the plant. The uniform nature of the ice and the heavy load of slush in the water are visible, along with small slush field.

Figures 12, 13, and 14 show slush accretion on the ice face and blowhole development during the afternoon of 6 January.

A closeup view of the uniform, porous, granular ice that was forming on 6 January is shown in Figure 15.

Figure 16 is an exploration pit showing a coarse granular crust over loose granular ice. The sandy color in the pit is an artifact of light.

Figure 17 looks northward from the plant in the afternoon. The icefoot of the morning (Figure 7) reaches into the distance from the bottom of the picture; ice accreted since morning shows at the left.

In Figure 18 a blowhole is shown that formed, was active, and became extinct in less than a day.

Figures 19 and 20, taken on 10 January, show the poor lasting quality of the granular ice of 6 January. The icefoot has nearly melted away and wave-tossed sand has been deposited and has been held on the ice.

Figure 21 is a view northward from the plant on 24 January. Residual blocks from the icefoot of 6 January lie on the beach in right two-thirds distance. In the terminology we have used in previous ice reports, these blocks constitute what there is of the onshore ridges A and B. In the center of the picture lies rough ice of the frozen first lagoon, while ridge C with prominant blowholes lies along the open water at left.

In Figure 22 the combined ridges A and B are represented by residual blocks on the beach in left distance, rough ice of the frozen first lagoon passes into the left background from lower right. Ridge C with blowholes lies at the edge of the open water.

Figure 23, taken in the morning of 25 January after the major storm during the night of 24 January, shows the spray-ice covered bluff at the visitors center.

Figure 24 presents the spray-ice covered beach on 25 January, with greatly augmented ridge C at left.

In Figure 25 the view is southward along the face of augmented ridge C (at left). A rough second frozen lagoon composed of spray-cemented ice-balls has been formed by the storm. In two-thirds distance at the right, wave action is forming ridge D.

Figure 26 is a view lakeward from the top of ridge C. The relatively uniform new iceballs from the storm (in the background) contrast with fresh spray ice on larger older sandier iceballs of the ridge (foreground).

In Figure 27 the second frozen lagoon dominated by new iceballs appears in front of wave action on developing ridge D in the background. A closer view of developmental activity on ridge D is presented in Figure 28. Figure 29, at the face of ridge D, shows iceballs, slush and spray being deposited on the developing ridge.

Figure 30 looks northward along the sandy residua of ridges A and B. The frozen first lagoon in left center rises to rough ridge C at upper left, taken 31 January.

In Figure 31 the view is southward along the remains of ridges A and B. The first lagoon and ridge C are at right.

The view in Figure 32 is northward along the top of ridge C. The scalloped ridge face, extinct blowholes, and a heavy dominance of iceballs show clearly. The second lagoon and ridge D at left show some sand color, but less than does ridge C.

Ice balls of several sizes present on the lakeward face of ridge C are shown in Figure 33.

In Figure 34 the view is southward along the top of ridge D at a point north of the plant. The shiny objects on the ridge surface are angular pieces of sheet ice 1/2" to 3/4" thick. To the right of the ridge is a belt of loose trash ice. Closeup detail of the surface of ridge D is given by Figure 35. Angular pieces of sheet ice are cemented down by frozen spray and dusted with new snow.

Figure 36 looks shoreward from the second lagoon toward the face of ridge C. Several sizes of iceballs lie in front of the ridge. Two extinct blowholes are present in the ridge.

Figure 37 shows Dr. Samuel Mozley holding a "medium sized" iceball in front of the ridge C face.

In Figure 38 Dr. Mozley and Jon Barnes core for psammon through the ice of the first frozen lagoon.

The view northward from the plant on 9 February is shown in Figure 39. A recent snowfall has obscured most of the details of the icescape.

Figure 40 presents the view southward from a point south of the plant. From left to right: the residua of ridges A and B, the first lagoon, ridge C with blowholes, the second lagoon, and ridge D just below the ice edge in the distance.

Figure 41, taken on 9 February from the roof of the visitors center, is partly obscured by recent snowfall. Ridge D shows as a continuous belt of smoother white just below the top of the light pole at the right. Landward from ridge D is the rough surface of the second lagoon. Ridge C with blowholes shows behind the lower part of the pole.

This same sequence of ridges and lagoon is identifiable in the rooftop shots through 20 March. (21 February is shown in Figs. 42, 43, 44; 2 February in Fig. 45; 7 March in 46, 47, 48; and 20 March in 49, 50, and 51.) Figures 44, 48, and 51 comprise the pertinent series with details shown by the intervening figures.

Figure 45, from our overflight of 22 February, shows the ridges and lagoons with a large ice field outside ridge D. Figure 52, on 3 April,

shows the demise of the residua of ridges A and B, and the beginning of shore erosion in the foreground where the ice has melted. Figure 53, south of the plant shows the demise of ridge C and the first lagoon. Figure 54 from the rooftop shows remnants of ridge C behind the lower part of the light pole.

The shore ice structures and characteristics previously seen have been repeated with variations in the winter of 1971-72.

The primary variations from last winter were:

1. The formation of the initial icefoot of homogeneous coarse granular slush ice, contrasted with initial icefoot compositions of iceballs and spray ice previously seen.
2. The presence of pressure ridges against the face of ridge D, and in the second lagoon between ridges C and D, which had not been so definite in previous winters.

With these exceptions, the basic patterns of shore ice structure, of shore ice composition, and of modes of ice formation and destruction were as had been observed previously.

LEGENDS FOR FIGURES

Figure 1. Frozen beach north of the plant. Photo by Ames/Warnock (A/W). 13 December 1971.

Figure 2. Frozen beach south of the plant. Photo by A/W. 13 December 1971.

Figure 3. Frozen beach north of the plant. Photo by A/W. 29 December 1971.

Figure 4. Frozen beach south of the plant. Photo by A/W. 29 December 1971.

Figure 5. Frozen beach north of the plant. In the center foreground the edge of the frozen beach is being eroded by run back of wave wash. 5 January 1972.

Figure 6. Detail of wave erosion at edge of frozen beach, water and unfrozen beach at left. 5 January 1972.

Figure 7. View from bluff at visitors center looking northwest. This picture shows the first icefoot of the winter, formed during the night of 5-6 January, situated at the water's edge and on the foot of the beach, morning of 6 January 1972.

Figure 8. New icefoot on the beach south of the plant. View is to the south. An "extinct" blowhole in the foreground. 6 January 1972.

Figure 9. South of the plant. Solid very sandy ice directly on the foot of the beach. Probably the initial icefoot. 6 January 1972.

Figure 10. Frozen wave-wash on the beach inshore of the block in previous picture. Perhaps an initial high wave loaded with slush. 6 January 1972.

Figure 11. Looking south along the ice face south of the plant. Showing the heavy load of slush in the water and a small slush field in the two-thirds distance. 6 January 1972.

Figures 12-14. Slush accretion on the ice face and blowhole formation south of the plant in the afternoon. 6 January 1972.

Figure 15. Porous coarse granular slush ice which comprised the ice formations of 6 January 1972.

Figure 16. An exploration pit, showing a coarse granular crust over loose granular slush ice. 6 January 1972.

Figure 17. Looking north from the plant during the afternoon. The ice face of the morning (Figure 7) extends into the distance from the bottom of the picture. Slush ice accretion during the day at the left. 6 January 1972.

Figure 18. South of the plant. An extinct blowhole which formed, was active, and was cut off by outer ice all in less than a day. 6 January 1972.

Figure 19. Beach north of the plant with residual icefoot of very sandy ice. Photo by A/W. 10 January 1972.

Figure 20. Beach south of the plant with icefoot partially covered by fresh sand. Photo by A/W. 10 January 1972.

Figure 21. North of the plant. Scalloped residual icefoot (residua of ridges A and B) on the beach in upper right. Rough frozen first lagoon up the left center. Ridge C with prominent blowholes along the water at left. Photo by A/W. 24 January 1972.

Figure 22. South of the plant. Residua of ridges A and B on beach at left, the rough frozen first lagoon in center, and ridge C at right. Photo by A/W. 24 January 1972.

Figures 23-29. After the storm of 24 January:

Figure 23. Spray-ice covered bluff inshore of the beach at the visitors center. Photo by Jon Barnes. 25 January 1972.

Figure 24. Spray-ice covered beach north of the plant. Ridge C at left greatly augmented with fresh spray ice and iceballs. Photo by Jon Barnes. 25 January 1972.

Figure 25. Looking south along the augmented ridge C (at left). A rough second lagoon predominantly of iceballs has formed. In two-thirds distance at right, ridge D is forming. Photo by Jon Barnes. 25 January 1972.

Figure 26. The rather uniform new iceballs comprising the second lagoon. From the top of ridge C and showing fresh spray ice on older

sandier iceballs in the foreground. Mitten for scale. Photo by Jon Barnes. 25 January 1972.

Figure 27. The iceball covered second lagoon with wave action along forming ridge D. Photo by Jon Barnes. 25 January 1972.

Figure 28. Approaching ridge D. Wave action appears to be contributing slush ice and spray ice to the ridge growth. Photo by Jon Barnes. 25 January 1972.

Figure 29. The face of ridge D receiving iceballs, slush and spray. Slush-filled water at right. Photo by Jon Barnes. 25 January 1972.

Figure 30. Looking north along the sandy residua of ridges A and B north of the plant. At left the frozen first lagoon. Ridge C at upper left and center distance. 31 January 1972.

Figure 31. North of the plant. Looking south along the residual ridges A-B. The first lagoon and ridge C at right. 31 January 1972.

Figure 32. Looking north along the top of ridge C. Extinct blowholes and iceballs. In the upper left the second lagoon and ridge D show some sand color. Beyond ridge D is a field of snow-covered ice. 31 January 1972.

Figure 33. Iceballs along the lakeward face of ridge C. Glove for scale. 31 January 1972.

Figure 34. North of the plant facing south along the top of ridge D. Shiny objects are angular pieces of broken sheet ice 1/2" to 3/4" thick. To the right of the ridge is a belt of loose trash ice. 31 January 1972.

Figure 35. Angular pieces of sheet amid spray ice and snow on top of ridge D. 31 January 1972.

Figure 36. Looking shoreward from the second lagoon to the face of ridge C. Several sizes of iceballs on the lagoon surface and two extinct blowholes on the ridge. 31 January 1972.

Figure 37. Dr. Samuel Mozley holds a "medium sized" iceball in front of the face of ridge C. 31 January 1972.

Figure 38. Dr. Mozley and Jon Barnes core for psammon through the ice of the first lagoon. 31 January 1972.

Figure 39. View northward from the plant after a fresh snow. Photo by A/W. 9 February 1972.

Figure 40. View southward from the plant. From left to right: the beach, residua of ridges A and B, the first lagoon, ridge C with blowholes, a portion of the second lagoon, ridge D, and a field of (loose?) ice. Photo by A/W. 9 February 1972.

Figure 41. View southwestward from roof of the vistors center. Ridge C with blowholes behind the lower part of the light pole, the

second lagoon, ridge D (continuous belt of white just below top of pole), and a large field of ice floes. Photo by A/W. 9 February 1972.

Figure 42. Sand-melting of the ice structures north of the plant. The residua of ridges A and B lie on the beach at right. The less sandy first lagoon begins at lower left. Very sandy ridge C with iceballs crosses from below left center toward the headland. The second lagoon lies lakeward of ridge C and is less sandy. Ridge D not distinct. Photo by A/W. 21 February 1972.

Figure 43. Melting ice structures south of the plant. Residua of ridges A and B on the beach at the left edge of the ice. The first lagoon with stripes of sandy ice lies between the beach and ridge C with its blowholes. The second lagoon and parts of ridge D show over ridge C. Photo by A/W. 21 February 1972.

Figure 44. Ice in the same arrangement as in Figure 41. Sun-warmed sand in the ice has melted underlying ice and has been left as a surface lag concentrate. Photo by A/W. 21 February 1972.

Figure 45. Shore ice structure at Cook Plant after recent snowfall and with a large ice field present. What appears to be a pressure ridge lies against the face of ridge D in the right three

quarters of the picture. A smaller incomplete pressure ridge in the ice field curves from middle left toward the lower right. 22 February 1972.

Figure 46. North of the plant. Remnants of ridge C with remnants of second lagoon and ridge D to left, all with extensive lag concentrates of sand. Photo by A/W. 7 March 1972.

Figure 47. South of the plant. Further progression of melting and lag concentration of sand. Dark residua of ridges A and B on the beach edge, a band of water in the first lagoon, ridge C with blowholes, and parts of the second lagoon and ridge D visible in left center two-thirds distance. Photo by A/W. 7 March 1972.

Figure 48. View southwestward from roof of visitors center. Further melting and lag concentration of sand, the ice configuration the same as on 9 February. Photo by A/W. 7 March 1972.

Figure 49. North of the plant. Further melting and lag concentration of sand. First lagoon, ridge C, second lagoon, and ridge D from right to left. Photo by A/W. 20 March 1972.

Figure 50. South of the plant. From left to right: beach, first lagoon, ridge C, with parts of the second lagoon and ridge D visible in left center two-thirds distance. Photo by A/W. 20 March 1972.

Figure 51. From visitors center roof. Same ice configuration as on 9 February. More melting and lag concentration of sand. Photo by A/W. 20 March 1972.

Figure 52. North of the plant. Residual cakes of ridge C along the water's edge. Beach erosion in right foreground. Photo by A/W. 3 April 1972.

Figure 53. Residua of first lagoon and ridge C south of the plant. Photo by A/W. 3 April 1972.

Figure 54. Remnant blocks of ridge C visible just over the small buildings. View from roof of visitors center. Photo by A/W. 3 April 1972.

D. EFFECTS OF EXISTING THERMAL DISCHARGES ON LOCAL ICE BARRIERS

Fears that thermal plumes "will melt the shore ice and allow the winter waves to erode our beaches" are often expressed by concerned citizens opposing the construction or operation of generating stations.

Previous studies of this matter were carried out during the winters of 1969-70 and 1970-71 and are reported in Parts V and VIII of our report series.

On 1 February 1972 Mr. Yocum and Dr. Mozley visited the outfall area of the Consumers Power Campbell Plant at Port Sheldon, Michigan. The plume was surrounded by a heavy ice ridge and entirely protected from waves.

Figure 1 shows the mouth of the Campbell outfall, looking southeastward from the north shore of the outfall channel. The frozen condition of the upper part of the bare beach is indicated by the photographer's footprints becoming invisible partway back toward the yellow bucket in the background. He had just set the bucket down, and had walked in a straight line to the point where the picture was taken.

Figure 2 looks northward from the same position whence Figure 1 was taken. The area of bare beach decreases to zero in this picture. A yellow ice-ax 37 inches high, and standing on its handle behind an ice block, is shown for scale.

Figures 2 through 10 comprise a north to south panorama of the heavy ice ridge which surrounded the melt-spot of Campbell Plant on this day.

In Figures 6 and 7 faint wisps of steam can be seen rising from the discharge water.

In Figure 10 Dr. Samuel Mozley is shown taking a core for psammon.

We are well aware that heavy ice barrier protection of the Campbell Plant outfall does not represent the common condition, however, this condition is not unusual following severe weather conditions in January, February, and March. In our experience the common condition has been one of greater or smaller amounts of cake ice moving along the lakeward side of the Campbell plume.

On 22 February 1972 Dr. Ayers and Mr. Yocum overflew the Lake Michigan shore from Grand Haven, Mich., to Bailly Station at Burns Harbor, Indiana. The purpose of the overflight was to assess the shore ice condition and to ascertain whether the thermal plumes of the more readily accessible generating stations were causing melt away of the protective shore ice.

On this day the shore ice structure was generally well developed and solid, with an extensive field of cake ice along the outer edge of the shore ice complex.

Figures 11 and 12 show the outfall of Consumers Power Campbell Plant. Figure 11 illustrates the moving field of ice cakes of various sizes which was passing southward outside the Campbell plume. The shore ice ridges and lagoons were destroyed very locally by the plume.

In Figure 12 the view is northward from Campbell's Pigeon River intake toward the outfall and plume. The total distance along the beach from the south side of the outfall channel to the north Pigeon River breakwater is slightly over 3700 feet. The total length of the plume effect was substantially less than this distance, but perspective prevents a more accurate measure of its length.

The view in Figure 13 is from north to south across the outfall of Consumers Palisades Nuclear Plant. Flow from the plant has produced a melt spot in the second frozen lagoon and caused a minor perforation of ridge D.

Heavily scalloped ridge C continues up to each side of the discharge flume. Ridges A and B and the first lagoon are also intact up to the sides of the flume.

Beginning at Palisades and continuing to about New Buffalo, there were pressure ridges in the ice field and against the lakeward face of ridge D. The first part of the pressure ridge against ridge D shows in the background of Figure 13.

In Figure 14 the view is northward to and beyond Palisades Plant. The pressure ridge against the face of ridge D shows clearly; a minor pressure ridge within the ice field begins at the lower left corner and continues through the cloud shadow into the center distance. The area affected by the Palisades plume is insignificant in the total area of ice.

Figure 15 shows the shore ice structure at Cook Plant. A prominent pressure ridge lies against the face of ridge D, and a minor incomplete pressure ridge shows in the ice field in lower left. Heavily scalloped ridge C lies close to shore in left middle distance. One large and several small pressure ridges are present between ridges C and D in front of the plant.

Figure 16 shows the discharge plume of NIPSCO's Michigan City generating station. Shore ice continues up to the sides of the discharge channel mouth, and a large mass of heavy shore ice occupies the corner of the harbor at left center. The hazy nature of the picture is due to a heavy snow shower that was falling at the time.

The plume of NIPSCO's Bailly Station is shown in Figure 17. Recirculation from the plume to the circular intake crib is shown by loose ice cakes between the open plume water and the crib. Sandy colored shore ice extended well into the lake as evidenced by the comparative shortness of shore groins on the beach in left middle distance. The sandy shore ice reached up to the sides of the discharge flume. A heavy snow shower was falling at the time.

Figure 18 is a somewhat closer view of the Bailly Station in which the loose ice in the recirculation pattern and the shore ice configuration are clearer. Again, the heavy snow shower obscures detail.

Though the ice season of the winter of 1971-72 was short in duration, it was relatively severe in terms of quantity of ice formed and in quickness of ice formation. Despite the differences between this winter and the preceding two, the thermal plumes observed were behaving in the same manner as previously seen. Except at Consumers Campbell Plant, no melting of the beach icefoot was observed. Though Campbell Plant has in each winter melted some of the shore icefoot, the shore does not appear to have suffered erosion as a result.

The consistencies of in-ice plume behaviors at the plants we have observed twice or more are leading us toward the conclusion that each plant has an individual "typical" pattern of in-ice plume behavior.

LEGENDS FOR FIGURES

Figure 1. The mouth of the outfall channel of Consumers Power Campbell Plant at Port Sheldon looking southeastward from the north shore of the channel. 1 February 1972.

Figure 2-10. Comprise a north to south panorama around the Campbell Plant outfall.

Figure 2. Shore ice just north of Campbell Plant's outfall mouth, looking northward.

Figure 10. Looking south across the Campbell Plant outfall mouth. Dr. Samuel Mozley takes a psammon sample at the outfall mouth. 1 February 1972.

Figure 11. Plume of the Campbell Plant. 22 February 1972.

Figure 12. Looking northward along shore from Campbell Plant's Pigeon Lake intake to the plume in middle distance, showing the primary melt-spot and local destruction of the shore ice structure. 22 February 1972.

Figure 13. Looking south toward Palisades Nuclear Station with heavily scalloped ridge C reaching to the sides of the plant's discharge flume. Ridge D is interrupted immediately above the tip of the plane wing. 22 February 1972.

Figure 14. Looking northward toward the Palisades plume, showing its size in relation to the ice field and the shore ice structure. 22 February 1972.

Figure 15. Shore ice structure at Cook Plant. 22 February 1972.

Figure 16. Plume of NIPSCO Michigan City station showing shore ice at edge of discharge canal. Taken in a snow shower. 22 February 1972.

Figure 17. Plume of NIPSCO Bailly Station, showing recirculation of discharge water to the circular intake crib. Sandy colored shore ice extending to the sides of the outfall flume shows at left. Taken in a snow shower. 22 February 1972.

Figure 18. Shore ice extending to the flume sides at Bailly Station. Taken in a snow shower. 22 February 1972.